Technical Memorandum

DWRF Green Project Reserve Assistance
City of Ann Arbor, West High Service Pump Upgrades
DWRF Loan #7362

Stantec

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Summary

The purpose of this memorandum is to identify project components for the City of Ann Arbor West High Service Pump Upgrades project that may be eligible for funding through the DWRF Green Project Reserve Assistance and present a business case for these components.

The West High Service (WHS) pump station improvements project has an estimated loan amount of $6,000,000. This entire project cost should be considered for the Green Project Reserve due to the dramatically enhanced efficiencies achieved with the new pumping operation that includes new premium efficiency pump motors and variable frequency drives for flow control. The enhanced efficiencies are described in the following sections of this memorandum.

In summary of this memorandum, an increase in overall efficiency of 24% is expected with the station improvements by utilizing higher efficiency motors and changing the station flow control scheme from throttling valve control to variable frequency drive control. Additionally, by improving the efficiency of pump station operation, this will reduce the peak electrical demands on the utility and grid and reduce the cost of operation.

WHS Pump Station Background

The existing WHS pump station is located at the City of Ann Arbor Water Treatment Plant and was constructed in 1965. The station consists of three (3) 200 horsepower horizontal split case (HSC) pump in a vertical configuration that are used to pump water from the Water Treatment Plant finished water storage reservoir into the West High Service pressure district. These pumps are currently operated at constant speed. Flow control into the district is achieved using throttling butterfly valves on the discharge piping of each pump to maintain the discharge pressure into the WHS pressure district.

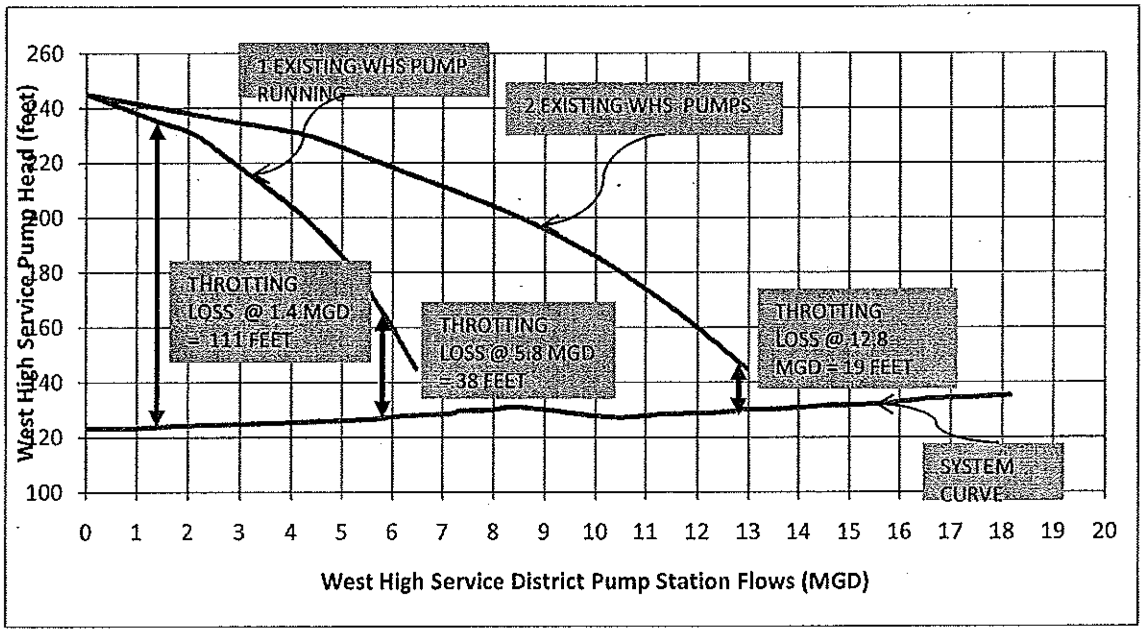
The existing motors are not premium efficiency. Additionally, the existing method of utilizing throttling valves for flow control is a very inefficient mode of operation and will be replaced with variable frequency drives on each pump. The station configuration will be modified to be increased from the current three (3) pump configuration to a four (4) pump configuration in order to better control flow over the wide range of WHS district demands creating a more efficient operation. The existing station and associated electrical equipment area have inadequate space for the new pumps, switchgear and variable frequency drives, therefore a new pump station on the WTP property is proposed.

The hydraulic efficiency of the existing pumps ranges from 37% to 87% over the demand range for the WHS district, based on the original pump curve from 1965. This curve is attached for reference.

The motor efficiency of the existing pump motors is assumed to be approximately 88% over this same range. Motor efficiencies were not typically published by motor manufacturers in 1965. Therefore historical data has been used which indicates that motors of this type, size and age ranged in efficiency from 88% to 92%. Based on the age of the motors and the fact that they have been rewound (which reduces motor efficiency relative to a brand new motor), it is assumed that the existing motors have an efficiency of 88%.

Recent operating tests have demonstrated that the existing WHS pumps are operating below the design pump curve, therefore the actual operating efficiencies of these pumps are lower than identified in the published curve. The hydraulic efficiencies used in the analysis presented in this memorandum are therefore considered to be conservatively high relative to the actual operating efficiencies.

More critical to the overall pumping efficiency of the existing station, the throttling valves further reduce the efficiencies of the pump station as the existing pumps draw considerably more horsepower and operate at Total Dynamic Head (TDH) conditions that are higher than is necessary to maintain district pressures, particularly at low flows. The excess head is dissipated across the throttling valves. The excess headloss with a throttling valve is demonstrated graphically in the following figure that shows the system curve and existing pump curves for both single and two pump operating conditions:



As can be seen from this figure, the excess head loss associated with throttling valves, particularly with low flow conditions, is significant.

WHS Station Improvements

The new high service pumps will be equipped with modern premium efficiency motors. Additional, these pumps will be driven by variable frequency drives such that demand and TDH will exactly match the district demand, thereby significantly reducing the horsepower draw at lower flow conditions. The following summarizes the design criteria used for the WHS Pump Station:

- N+1 design criteria (3 duty, 1 standby)
- Q_{peak} = 12,000 gpm at 128 feet TDH (4,000 gpm per pump)
- Power cost of $0.072/kWh
- VFD used for each pump

Four (4) multistage vertical turbine (VT) pumps are proposed, each equipped with a VFD. The VFDs will allow the flow rate to adjust up and down with demands, creating a significant advantage in efficiencies across the range of station flows as compared to constant speed pumps with throttling valves. The pumps were selected to provide a wide range of flows with 1, 2 and 3 pumps running, while maintaining good efficiencies across the majority of the pumping range.

Other configurations considered for this application were three (3) horizontal split case pumps and three (3) vertical turbine pumps. The three pump configurations offered lower hydraulic efficiencies over the range of design flows and higher horsepower motors. An option with four horizontal split case pumps was also discussed, but would have resulted in a larger station footprint, with associated higher capital costs. Therefore, no preliminary pump selection for this option was considered.

The efficiency of the new pump motors will be a minimum 95.8% premium efficient as defined National Electrical Manufacturers Association (NEMA). This efficiency will be used across the operating range of the motor.

To compare the efficiencies of the existing 1965 pumps with the new vertical turbine pumps and variable frequency drives, it is necessary to consider two other components: VFD efficiency and throttling valve efficiency (for the existing pumps).

VFD efficiency is straightforward; VFDs will be 97% efficient or better across the operating range and will come with power factor correction. VFDs are not 100% efficient due to heat losses associated with the electronics in the drive used to convert the electrical signal.

Throttling valve efficiency is defined by the following ratio:

$$\eta = 1 - \frac{P_{shaft} - P_{required}}{P_{shaft}}$$

Where:

P_{shaft} is the power applied to the pump shaft to meet a particular operating condition with the discharge valve throttled

$P_{required}$ is the power necessary to meet an a particular operating condition without throttling to dissipate excess head due to the constant speed operation of the pump

The values for P_{shaft} are taken directly from the BHP curve on the 1965 pump curve. The values for $P_{required}$ are calculated using the pump affinity laws applied to the 1965 pump and BHP curves.

The following tables demonstrate the operating efficiencies at different pumping ranges for the existing pumps with throttling valves versus the new vertical turbine pumps with variable frequency drives. The efficiency numbers are taken at the average value of each flow range. The tables also include the percentage of the year that the pumps operate in the range.

Table 1 – Existing Pump Efficiencies with Throttling Valves (3 x 200 HP HSC Pumps)

Pumping Range (gpm)	Hydraulic Efficiency	Motor Efficiency	Throttling Valve Efficiency	Total Efficiency	% of year operating in this Range	Weighted Efficiency
< 1,500	37.5%	88%	41%	14%	16%	2.2%
1,500 – 7,500	86.6%	88%	69%	52.6%	70%	36.8%
7,500 – 12,000	72%	88%	100%	63%	14%	8.8%
					Total Weighted Efficiency	**48%**

Table 2 – New Pump Efficiencies with VFDs (4 x 200 HP VT Pumps)

Pumping Range (gpm)	Hydraulic Efficiency	Motor Efficiency	VFD Efficiency	*Total Efficiency*	% of year operating in this Range	Weighted Efficiency
< 1,500	51%	96%	97%	*46.5%*	16%	7%
1,500 – 7,500	83.5%	96%	97%	*77.6%*	70%	54%
7,500 – 12,000	86%	96%	97%	*79.9%*	14%	11%
					Total Weighted Efficiency	**72%**

The overall pumping efficiencies for the two pumping conditions presented in Tables 1 and 2 is calculated with a weighted average of the above total efficiency values based on the percentage of a year that the station is operated within a particular pumping range. This results in overall weighted efficiencies of 48% for the existing pumps with throttling control and 72% for the new pumps with variable frequency drives over the range of station flows, taking into account pump efficiency, motor efficiency, and VFD or throttling valve efficiency. This equates to an increase of 24%.

The increase in overall efficiency results in an annual electrical cost savings of approximately $49,000 as shown in the table below.

Table 3 – Annual Electrical Savings

Pumping Configuration	Average Day kWh	Average Day Electrical Cost	Annual Electrical Cost
(3) HSC Pumps with Throttling Control	4,758	$354.04	$129,220
(4) VT Pumps with VFD Control	2,962	$219.79	$80,223
		Annual Electrical Cost Savings	**$48,997**

In summary of this memorandum, an increase in overall efficiency of 24% is expected with the station improvements by utilizing higher efficiency motors and changing the station flow control scheme from throttling valve control to variable frequency drive control.

Attachment: Existing 1965 Pump Curve
New Vertical Turbine Pump Curve and Cut Sheet (Goulds 20ELC)
Horizontal Split Case Pump Curve for 3 Pump Option (ITT-Goulds 3410)
Vertical Turbine Pump Curve for 3 Pump Option (Goulds 20GHC)

$$\begin{array}{r} 50,000 \\ 20 \\ \hline 1,000,000 \end{array}$$